Comparison of SS/W Absorbers for the SiD HCAL

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- *Motivation*
- *Single Pion Results*
- *e+e- -> Z (jets) Results*
- *Summary*

Motivation for Study

Can the geometrical thickness of the HCAL be reduced?

-> make B-field volume smaller

-> saves cost of magnet coil $\propto BR_2$

Keep 4 λ_I thickness of HCAL

-> use a denser absorber than SS, i.e., W

-> change to 2 X_0 sampling in HCAL (already proposal to double the sampling in the last 10 ECAL layers to 1.4 X_0)

Effects on PFA, Calorimeter performance?

2 X_0 W -> 0.7 cm/layer
1 cm Scintillator
4 λ_I requires 55 layers
-> 93.5 cm from HCAL IR to OR

.5 cm scintillator
-> 66 cm from HCAL IR to OR

1 X_0 SS -> 2.0 cm/layer
1 cm Scintillator
4 λ_I requires 34 layers
-> 102 cm from HCAL IR to OR

.5 cm scintillator
-> 85 cm from HCAL IR to OR

SD Detector – a Particle-flow Detector for the LC

Tracking :

- Multi-layer Si Vertex Detector
- ~1 cm -> ~7 cm radius, 5 layers
- Si-Strip Tracker
- ~20 cm -> ~1.25 m radius, 5 layers

ECAL :

- 30 layers, ~1.25 m -> ~1.40 m radius
- W(0.25 cm)/Si(0.04 cm)
- ~20 X_0, 0.8 λ_I
- ~5 mm X 5 mm cells

HCAL :

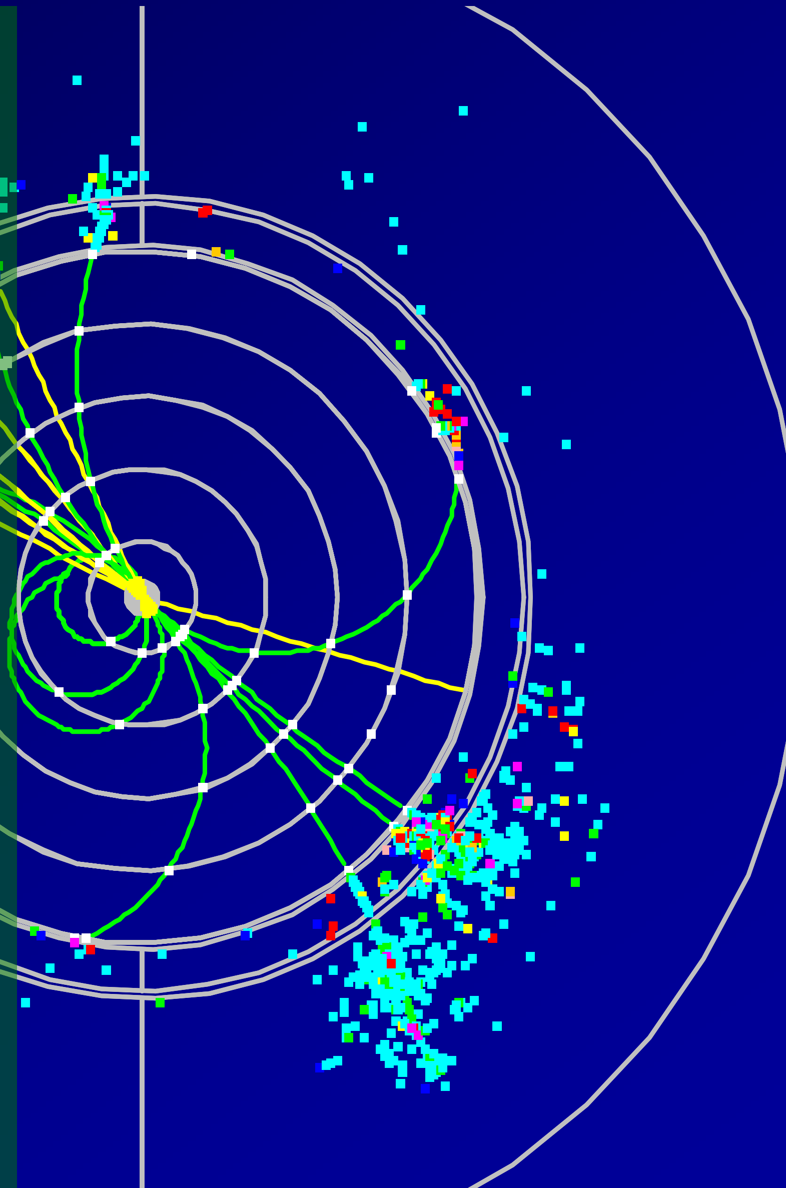
- 34 layers, ~1.45 m -> ~2.50 m radius
- SS(2.0 cm)/Scin(1.0 cm)
- ~40 X_0, 4 λ_I
- ~1 cm X 1 cm cells

Solenoid Coil :

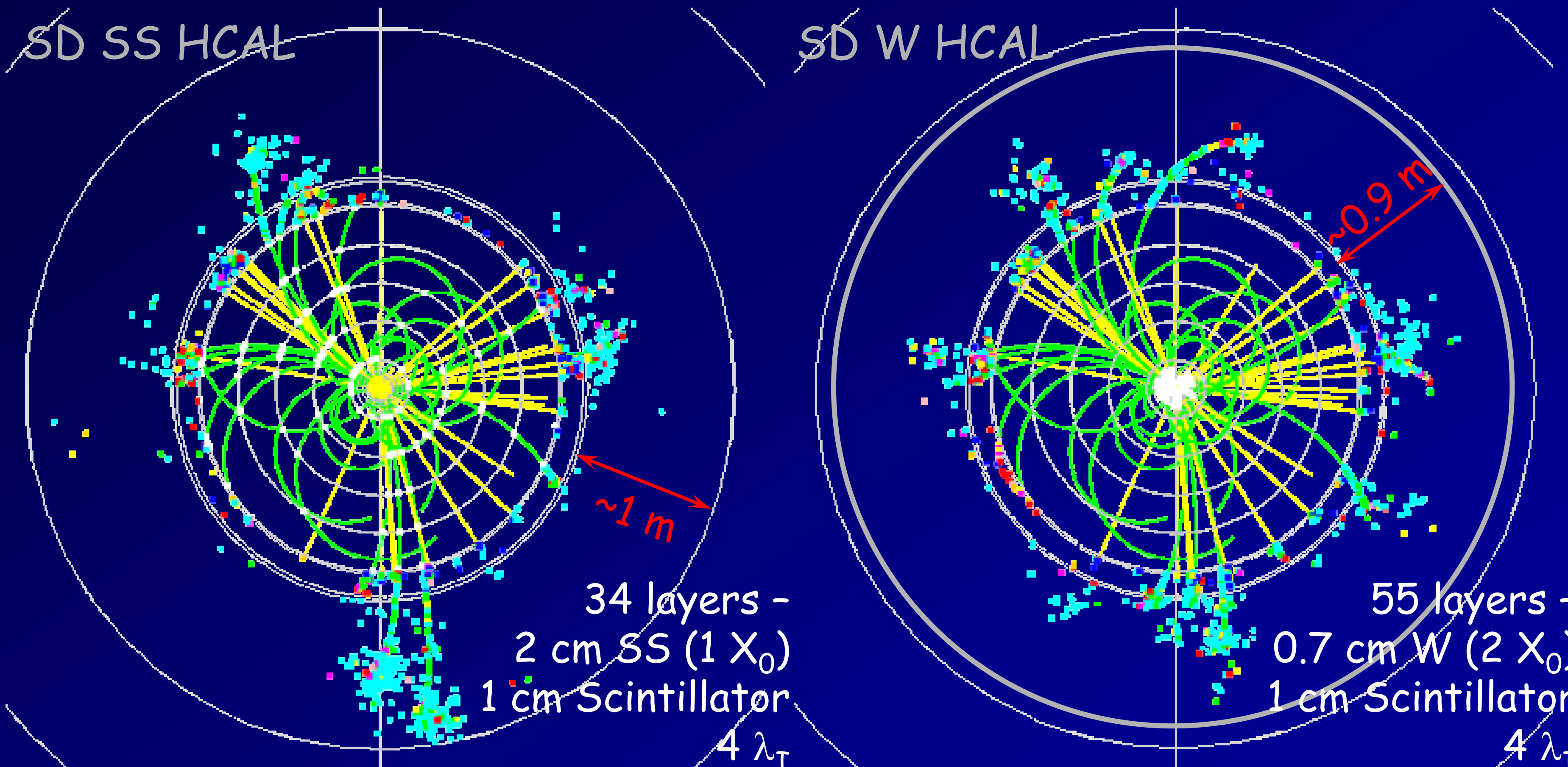
- 5 Tesla, ~2.50 m -> ~3.30 m radius

Muon (Tail Catcher) :

- ~3.40 m -> ~5.45 m

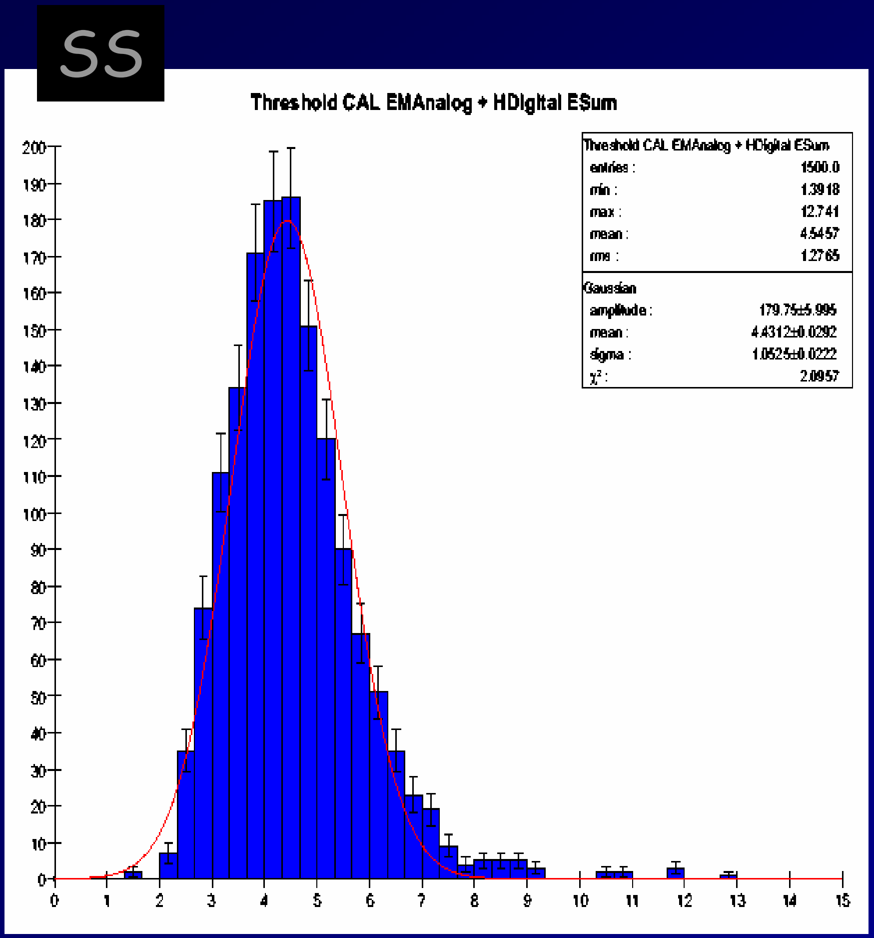


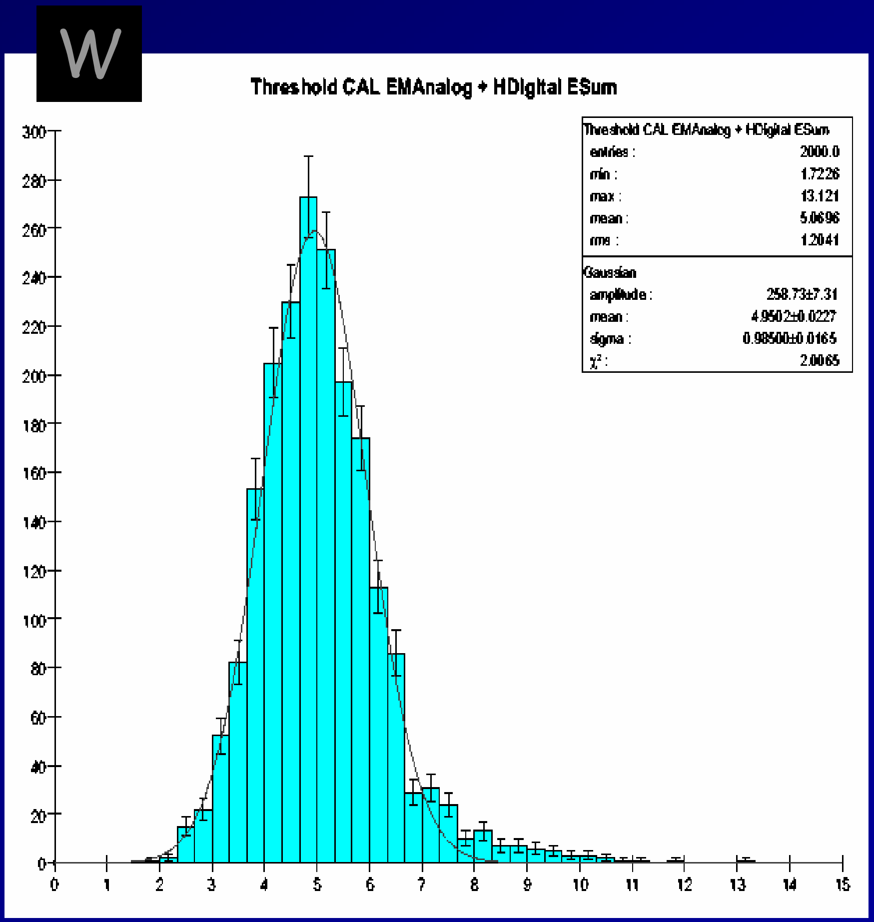
Z jets in SS/W HCAL



Different shower shape in W compared to SS?

Single 5 GeV Pion – E measurement with DHCAL



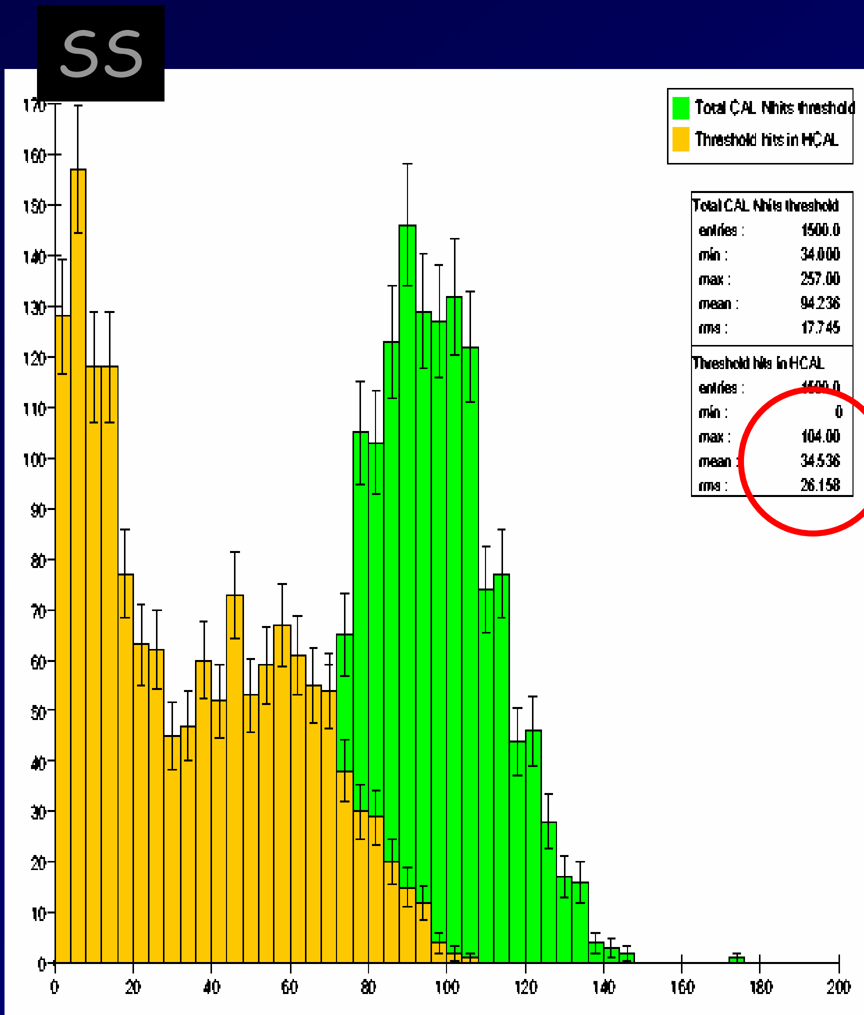


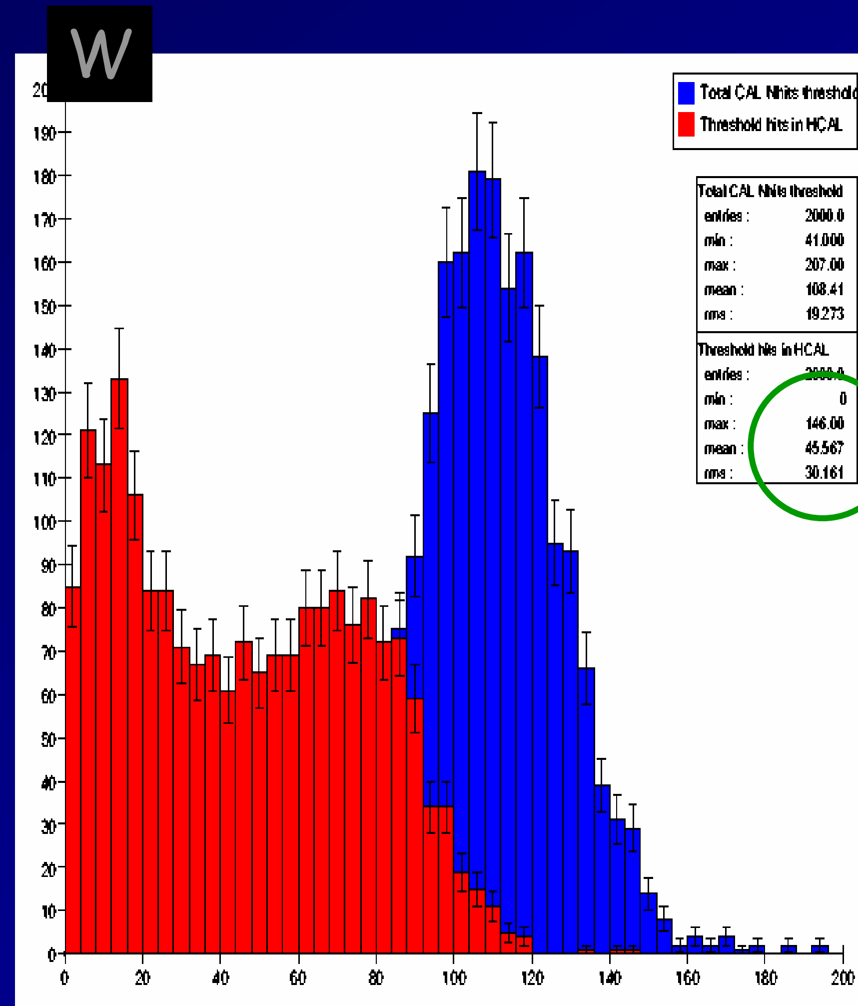
Energy measurement in calorimeter – Analog ECAL, Digital HCAL

-> σ/mean smaller in W HCAL

-> same behavior for analog HCAL, but smaller effect . . . Why?

Single 5 GeV Pion – Number of hits (1/3 mip thresh)



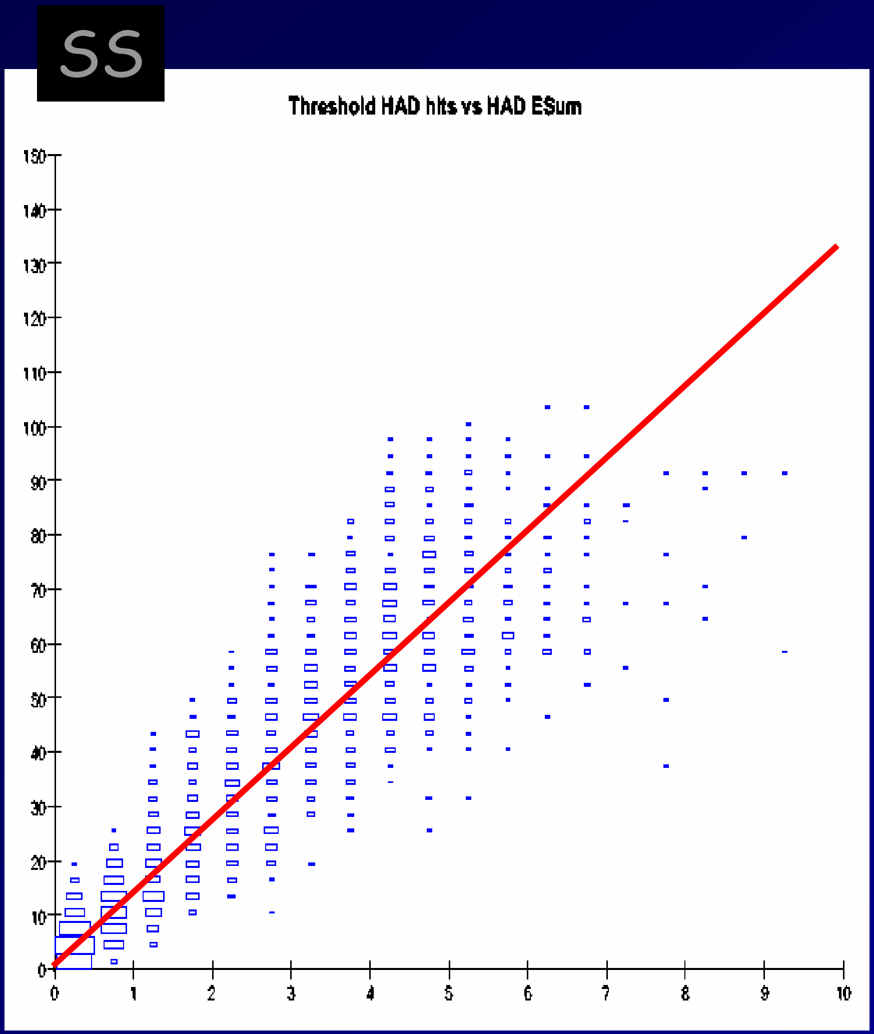


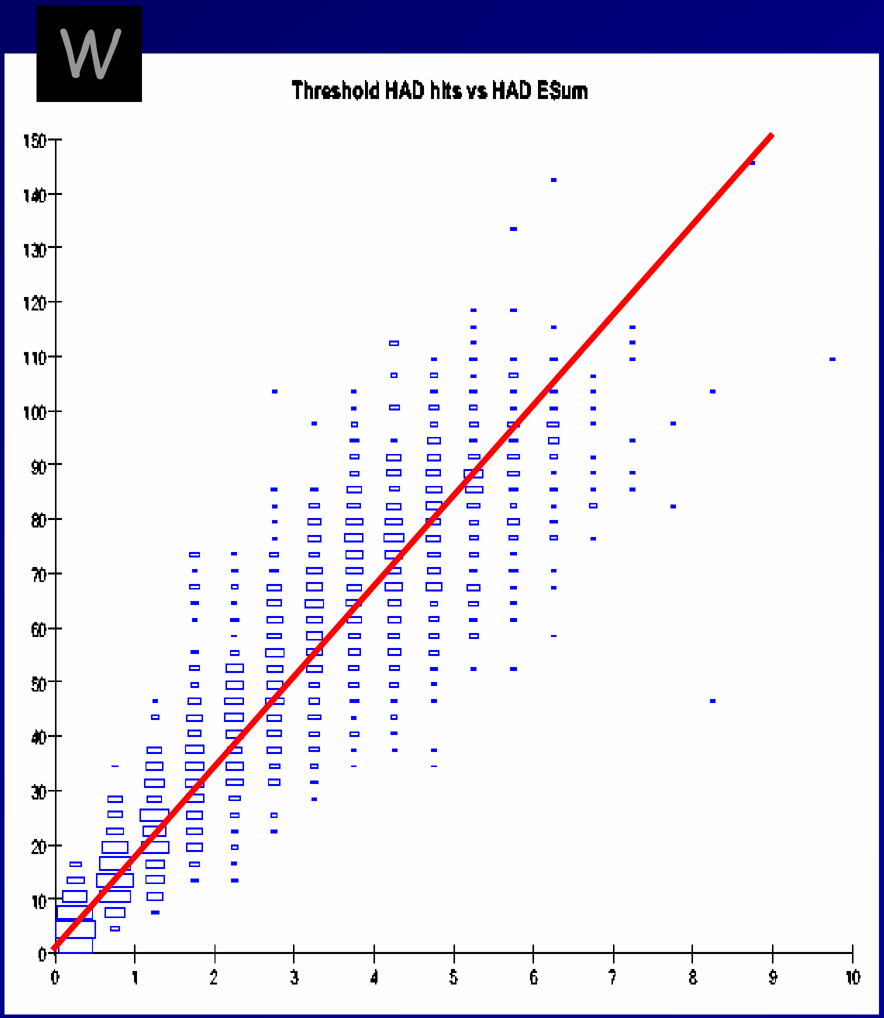
More hits in W HCAL than in SS

-> 30% more hits in the HCAL for W

-> better digital resolution for W!

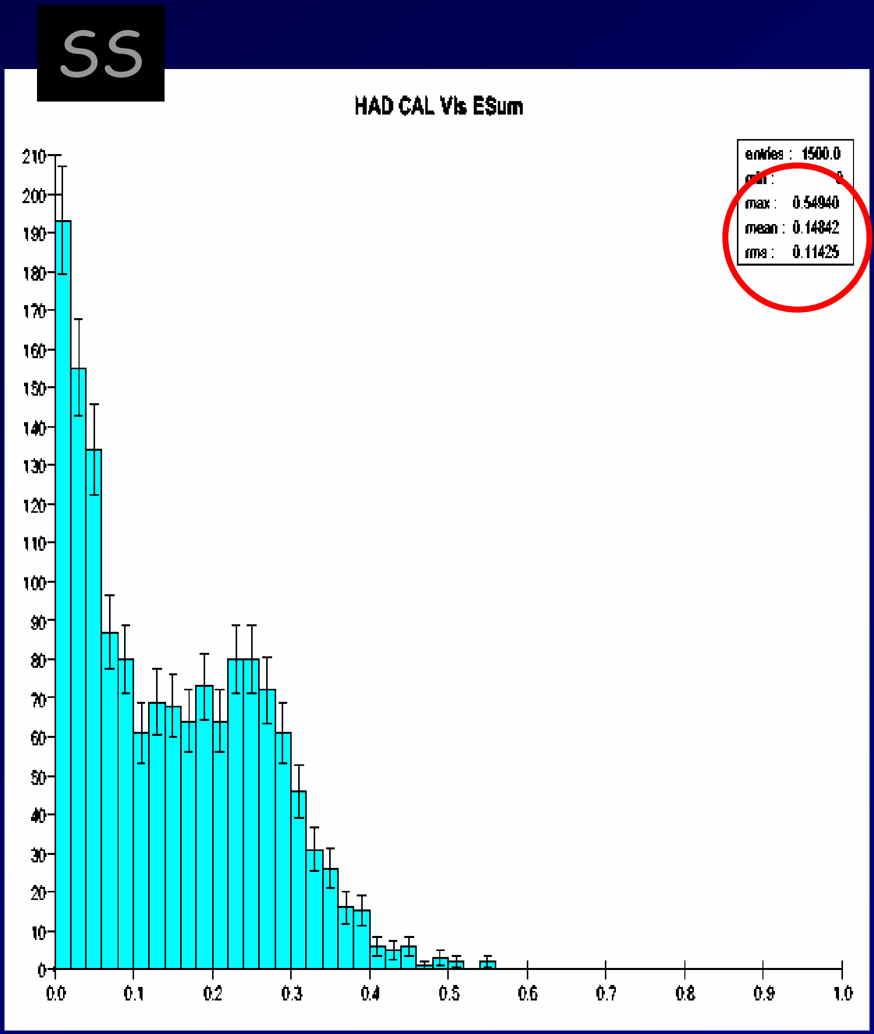
Single 5 GeV Pion - Linearity of hits vs E (HCAL)

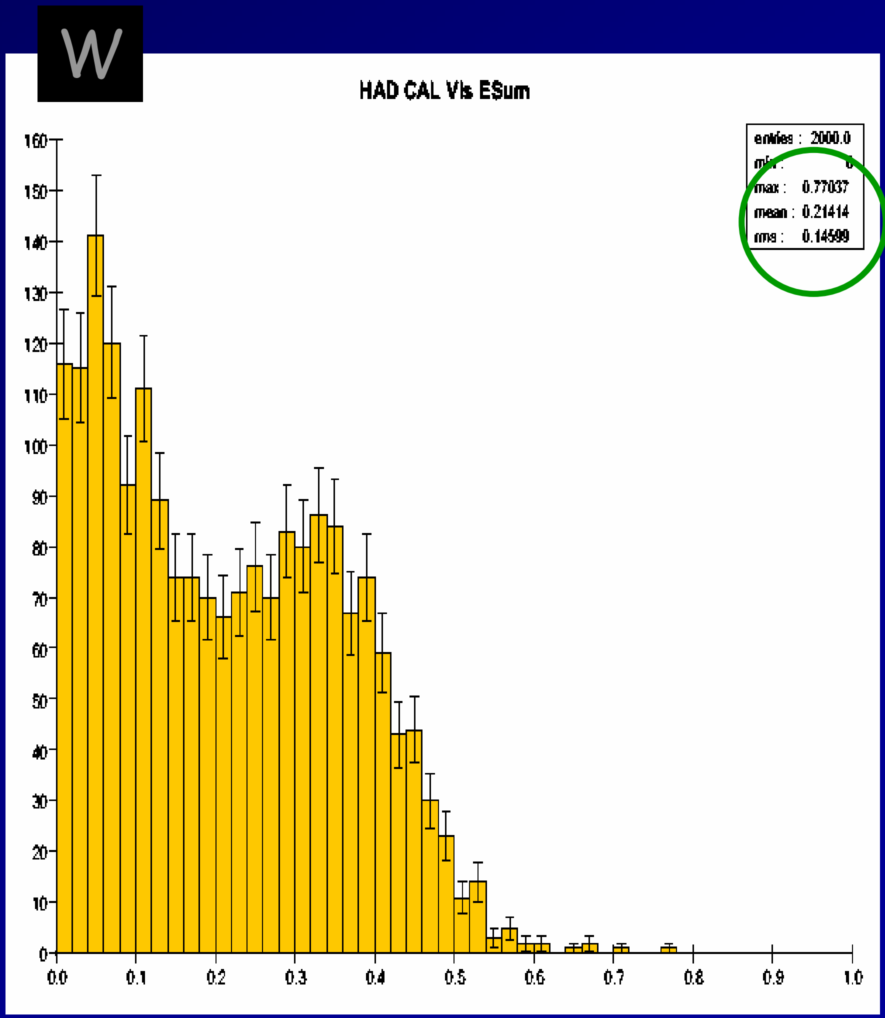




Both exhibit linear behavior for number of hits vs energy
-> more hits per GeV in W

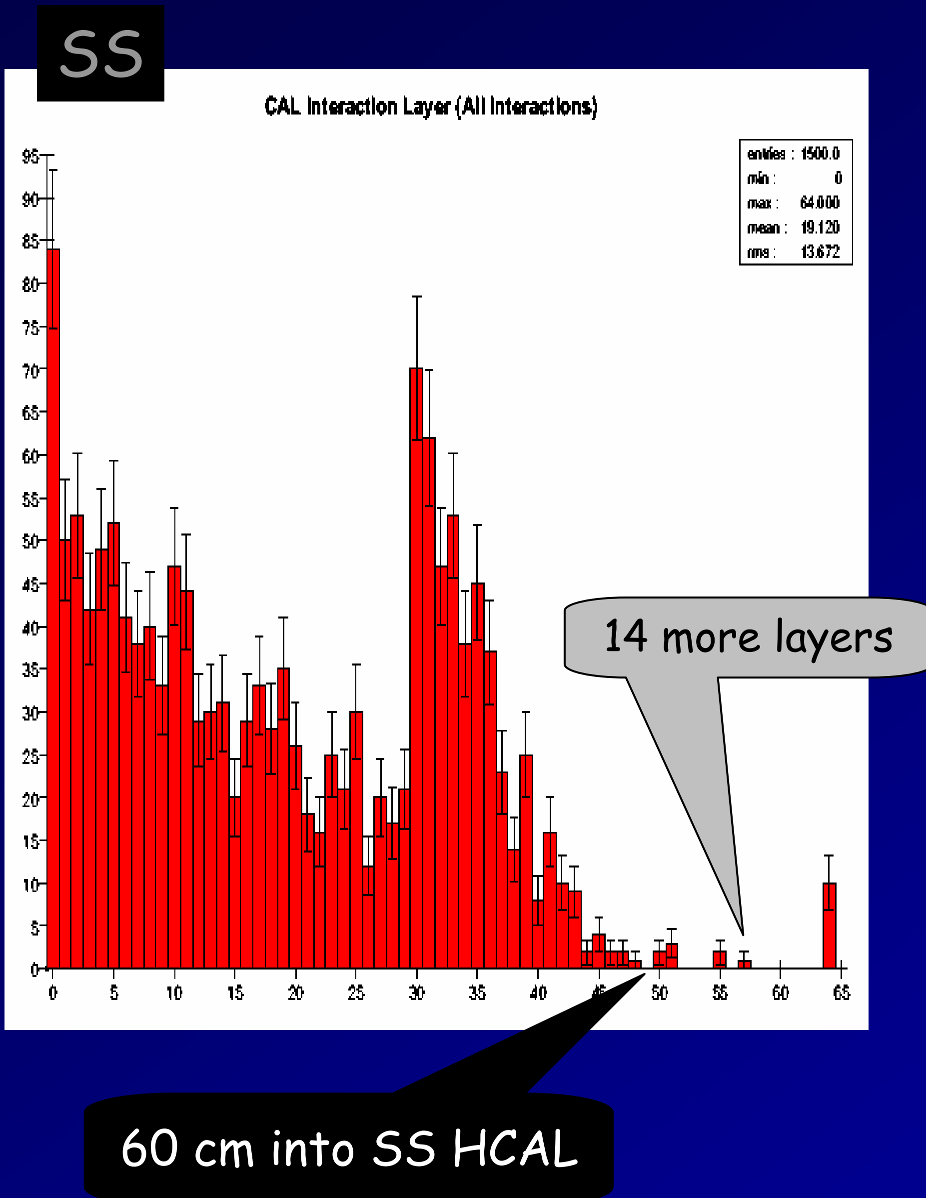
Single 5 GeV Pion - Visible Energy in HCAL

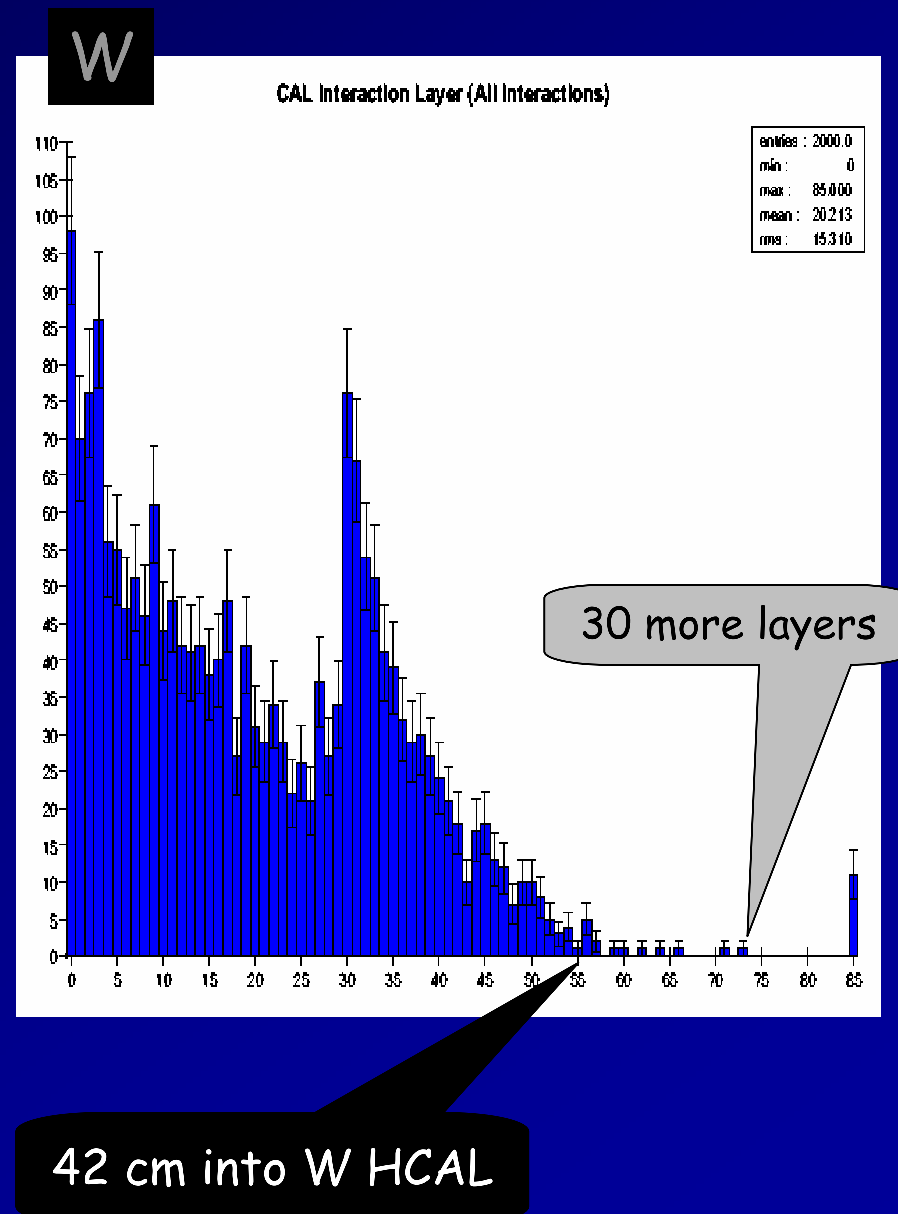




More visible energy in W HCAL

Single 5 GeV Pion - First Interaction Layer





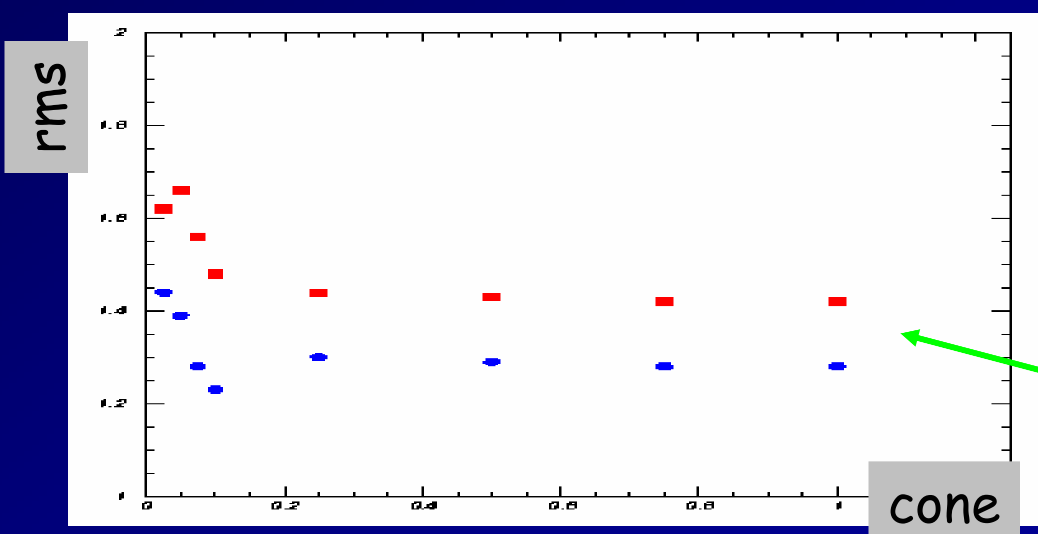
Single 5 GeV Pion - Shower Shape Analysis

SS

cone	mean (GeV)	rms	σ/mean	χ2
.025	2.07	1.62	.79	10.61
.05	2.96	1.66	.51	4.51
.075	3.63	1.56	.38	2.74
.10	4.08	1.48	.31	2.56
.25	4.76	1.44	.25	2.49
.50	4.85	1.43	.25	2.42
.75	4.86	1.42	.25	2.25
1.00	4.87	1.42	.25	2.45

W

cone	mean (GeV)	rms	σ/mean	χ2
.025	1.92	1.44	.78	9.36
.05	2.94	1.39	.41	4.29
.075	3.59	1.28	.31	2.42
.10	4.01	1.23	.25	2.35
.25	4.64	1.30	.23	2.70
.50	4.77	1.29	.23	2.50
.75	4.79	1.28	.23	2.41
1.00	4.80	1.28	.23	2.40



Energy in fixed cone size :
-> means ~same for SS/W
-> rms ~10% smaller in W

Tighter showers in W

Summary of Single Pion Results

Energy versus fixed cone size

-> means very similar for SS/W . . . however, the rms in the W HCAL was ~10% smaller than the SS

CAL Energy Sums

-> for analog energy sum with 1/3 mip threshold in the HCAL, sigma/mean is ~14% smaller in the W HCAL

-> for ECAL analog and HCAL digital - again, the sigma/mean was smaller in the W HCAL

-> for HCAL only when the pions deposited only mips in the ECAL, sigma/mean ~10% smaller in the W HCAL

CAL Number of Hits

-> total number of hits in the CAL, counting hits in ECAL and HCAL with a 1/3 mip threshold in the HCAL was 108 in W, 94 in SS

-> in HCAL alone, 46 in W, 35 in SS (30% more in W)

1) Tighter showers -> better PFA performance?
2) More hits -> better digital resolution

Motivation for Track-First P-Flow

Charged particles

~ 62% of jet energy

-> Tracker $\sigma/p_T \sim 5 \times 10^{-5}\, p_T$

~190 MeV to 100 GeV jet energy resolution

Photons

~ 25% of jet energy

-> ECAL $\sigma/E \sim 15\text{-}20\%/\sqrt{E}$

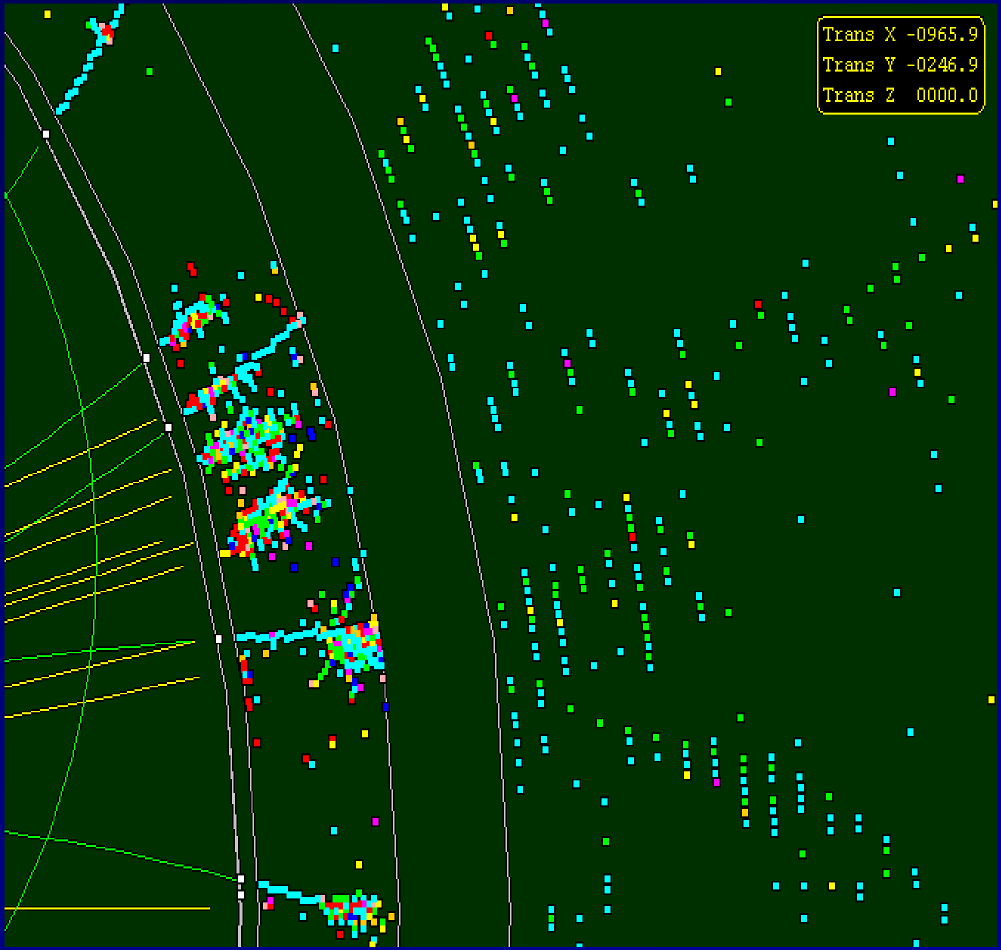
~900 MeV to energy resolution

Neutral Hadrons

~ 13% of jet energy

-> HCAL resolution not critical

~3 GeV to energy resolution



Also, since ECAL is dense, hadrons are optimally separated from photons (starting point of shower longitudinally)

-> 75% of hadrons shower after photon shower-max in ECAL

Track Extrapolation Particle-flow Algorithm

ANL, SLAC

1st step *- Track extrapolation thru Cal*

- substitute for Cal cells (mip + ECAL shower cone + HCAL cone : reconstruct linked mip segments + iterated in E/p hits in cones)

- analog or digital techniques in HCAL

- Cal granularity/segmentation optimized for separation of charged/neutral clusters

2nd step *- Photon finder*

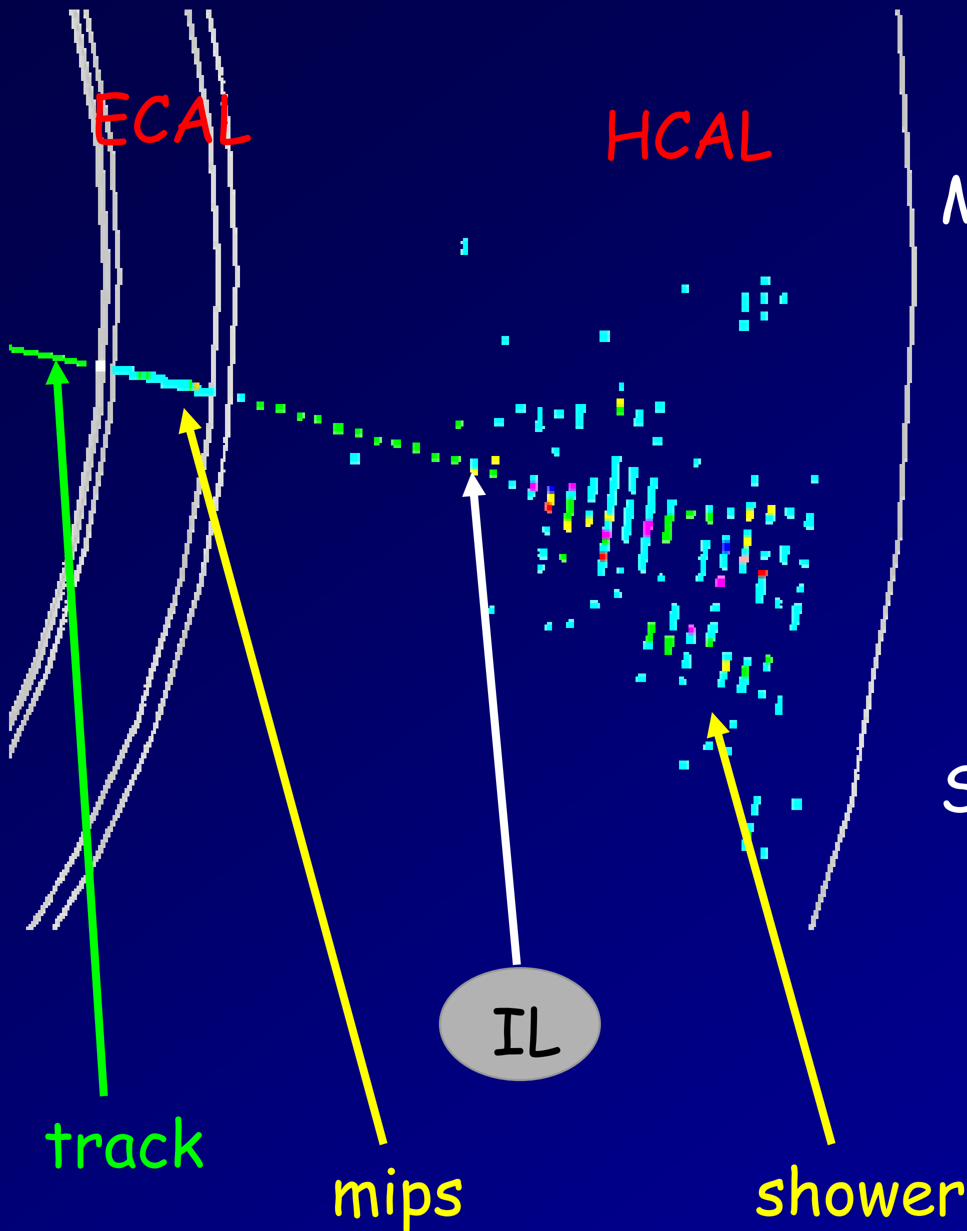
- use analytic long./trans. energy profiles, ECAL shower max, etc.

3rd step *- Jet Algorithm*

- tracks + photons + remaining Cal cells in jet cones defined by charged track jets (neutral hadron contribution)

- Cal clustering not needed -> Digital HCAL?

Shower reconstruction by track extrapolation



Mip reconstruction :

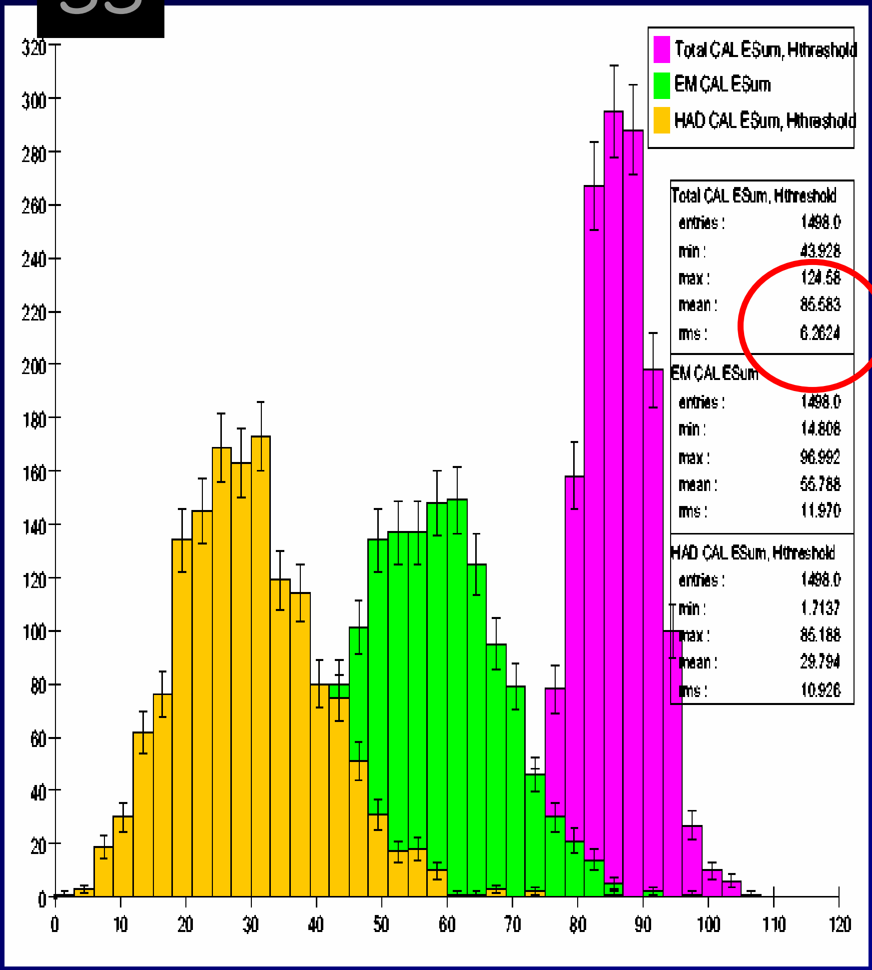
- Extrapolate track through CAL layer-by-layer
- Search for “Interaction Layer”
- -> Clean region for photons (ECAL)

Shower reconstruction :

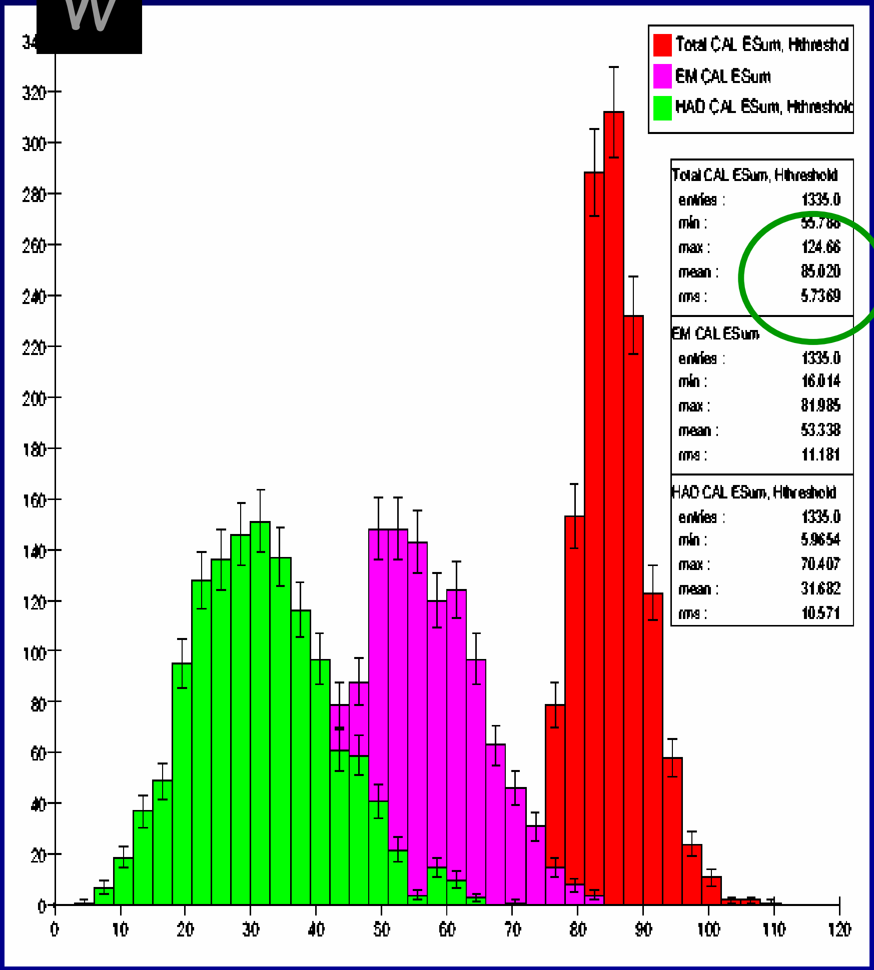
- Define cones for shower in ECAL, HCAL after IL
- Optimize, iterating cones in E,HCAL separately (E/p test)

e+e- -> Z (jets) – Energy Sums in Calorimeter

SS

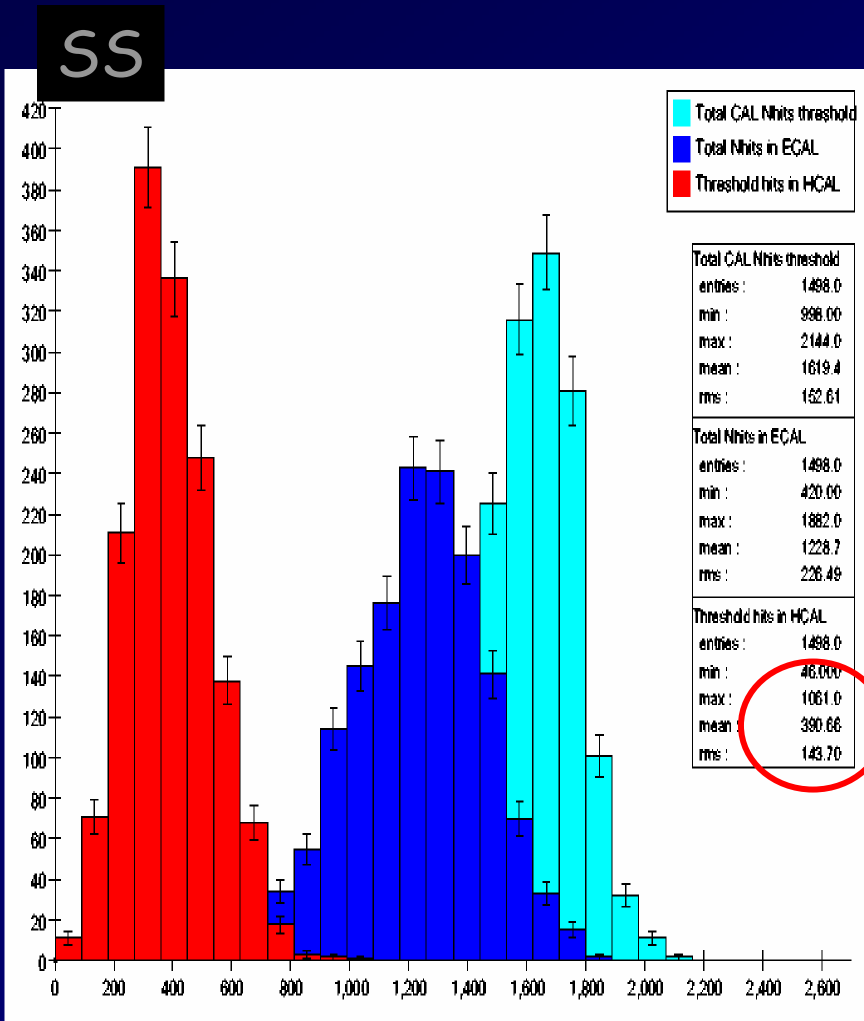


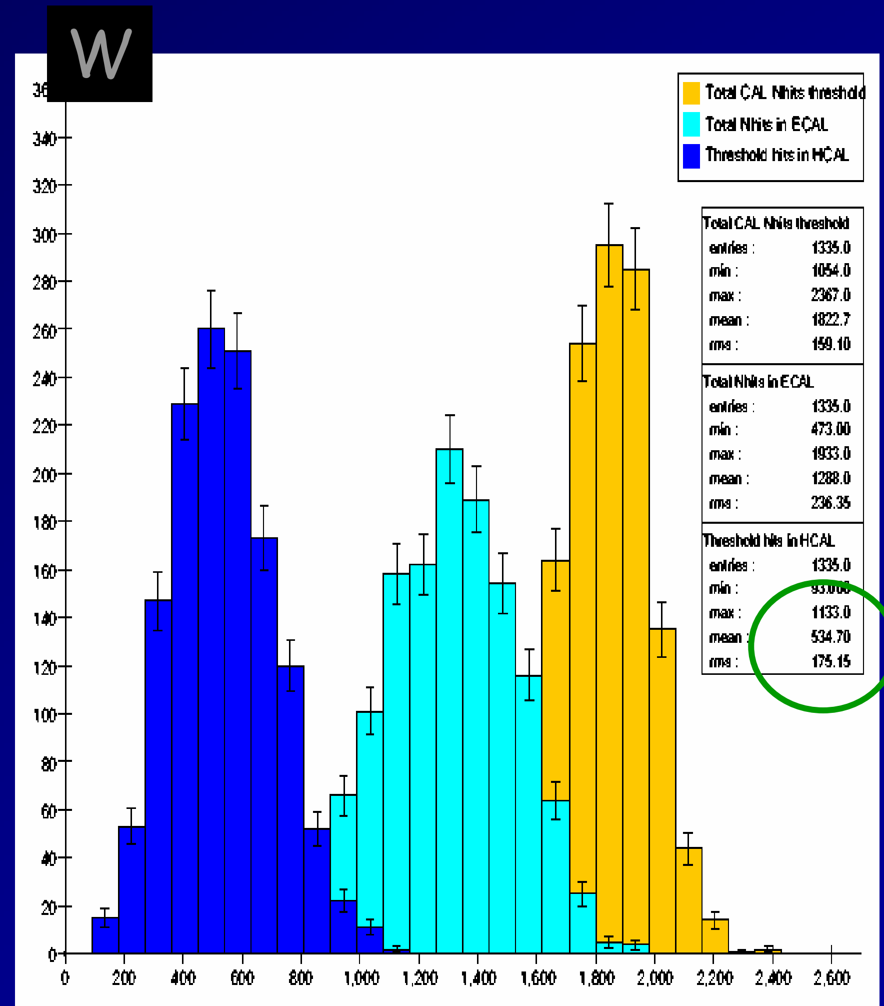
W



Total CAL energy sum tighter with W HCAL

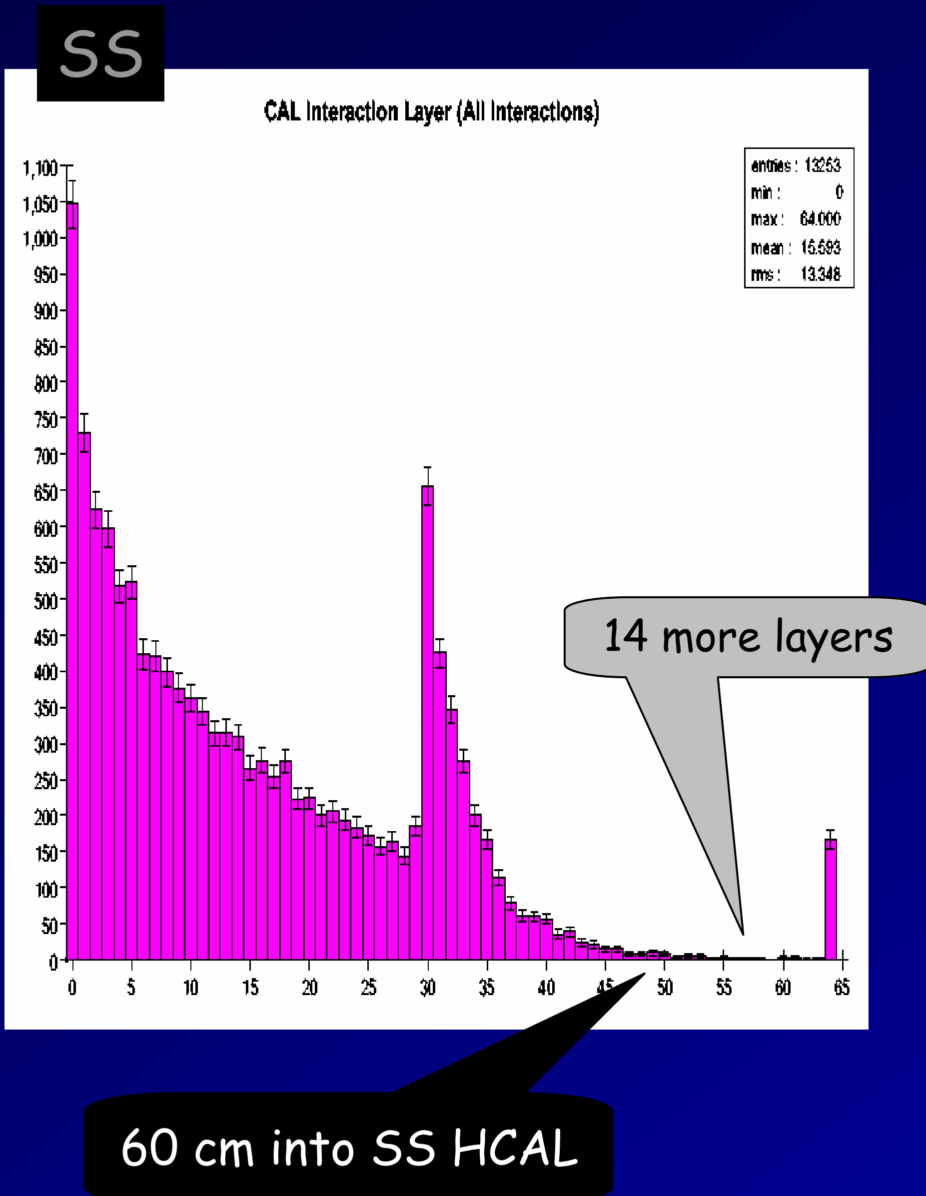
e+e- -> Z (jets) - Number of hits in Calorimeter

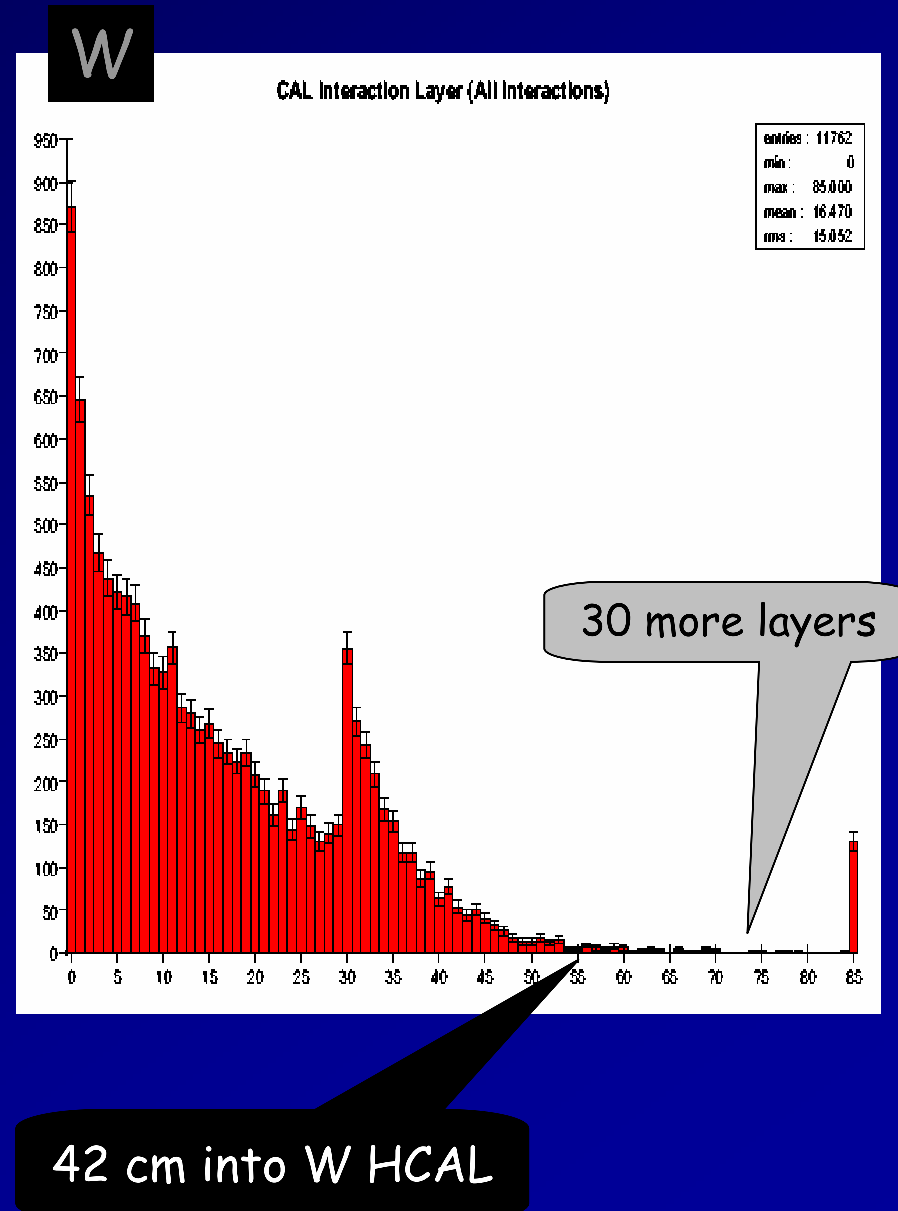




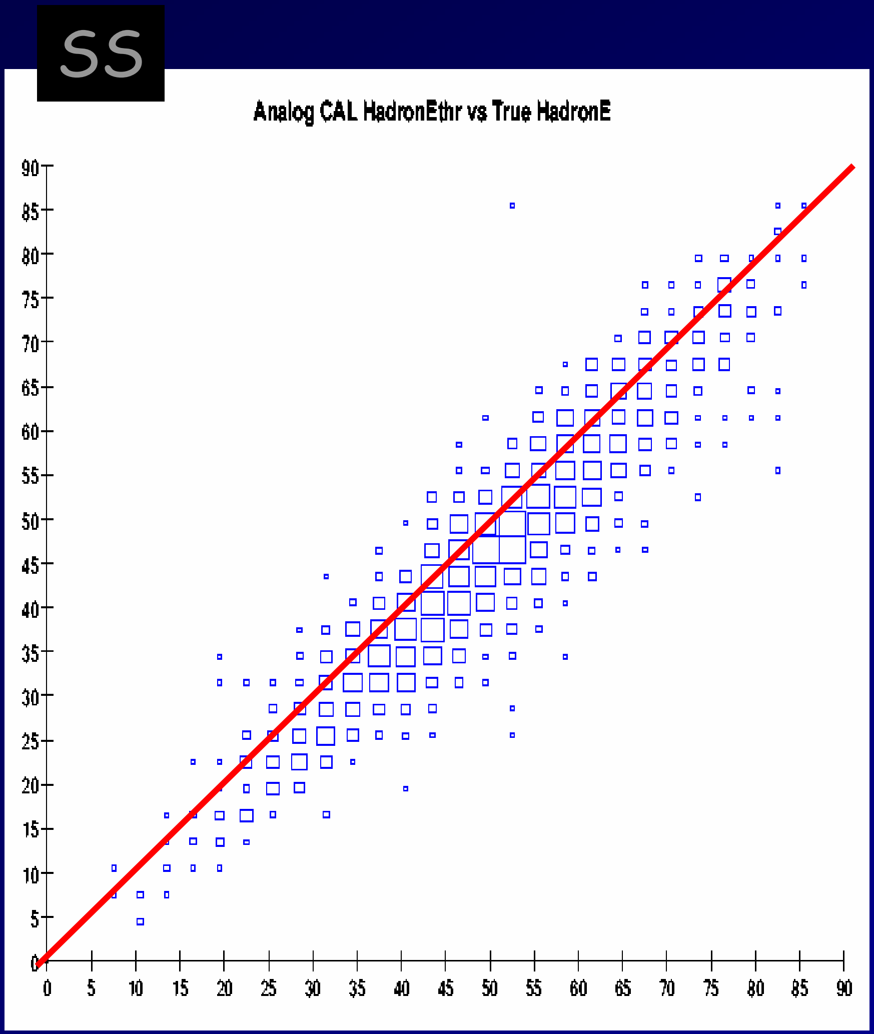
~ 35% more hits in W HCAL than SS
-> better digital resolution

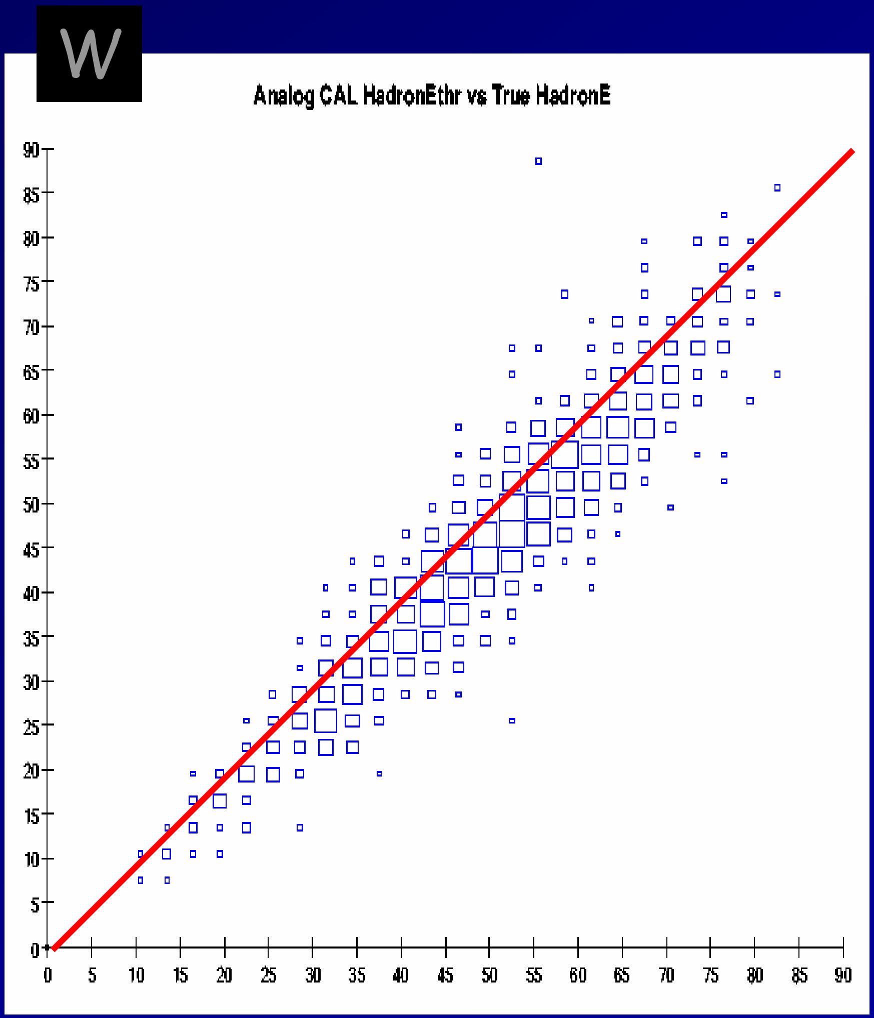
e+e- -> Z (jets) - First Interaction Layer





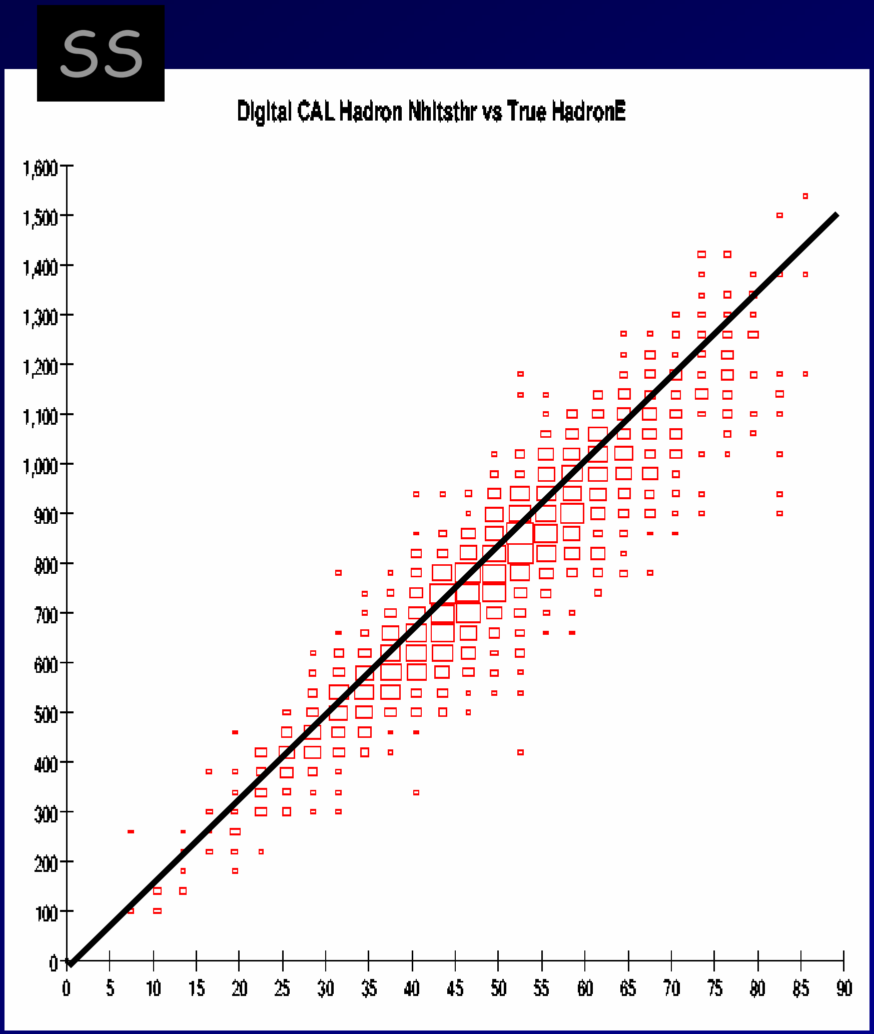
e+e- -> Z (jets) – Linearity of Energy Response

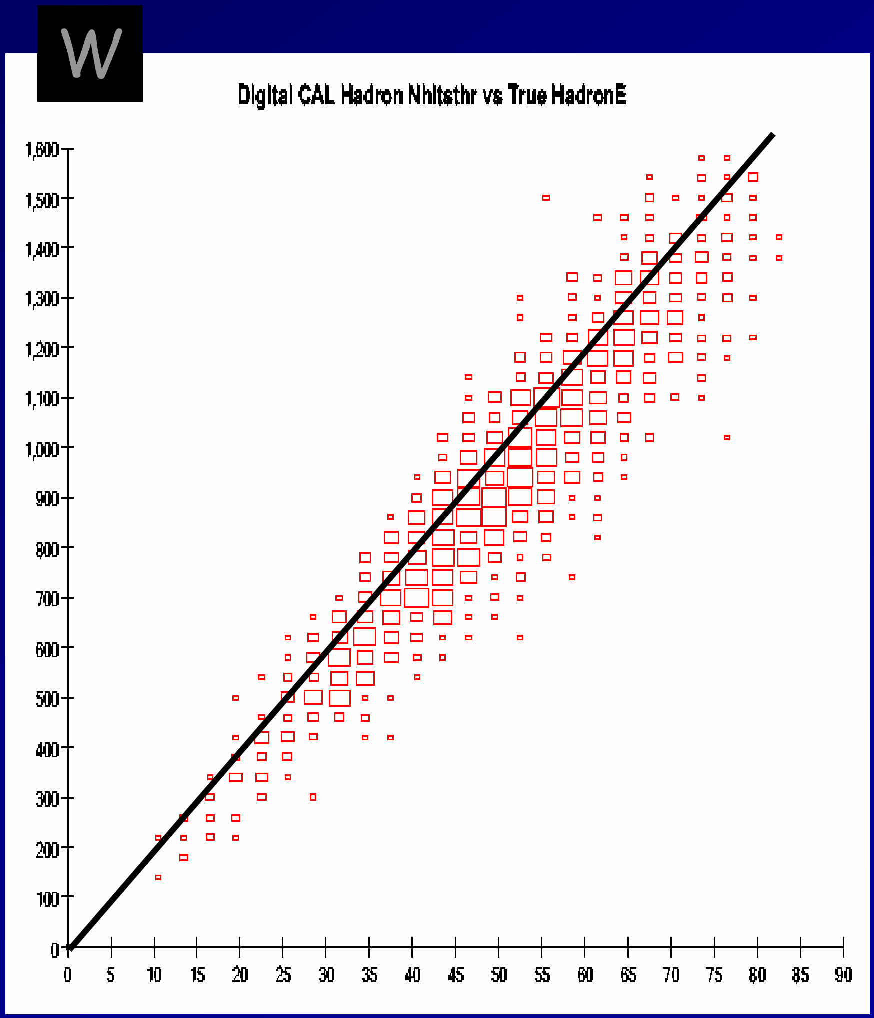




Both exhibit linear analog response

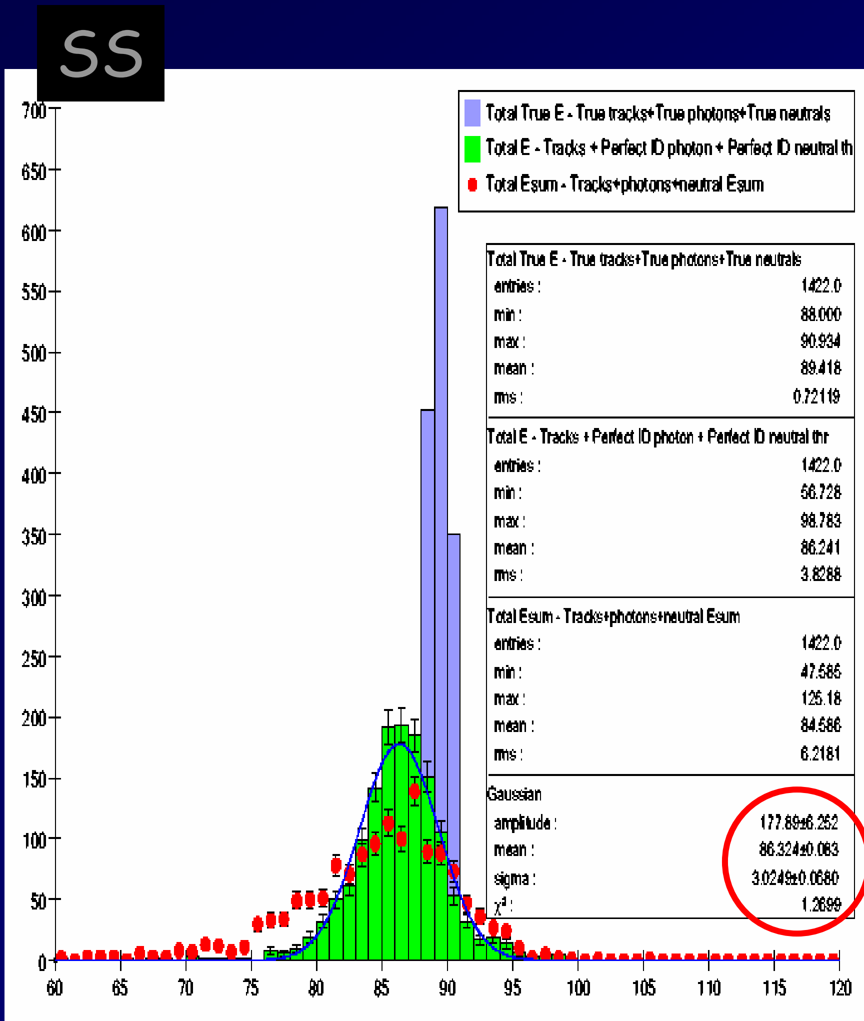
e+e- -> Z (jets) - Linearity of Hit Response

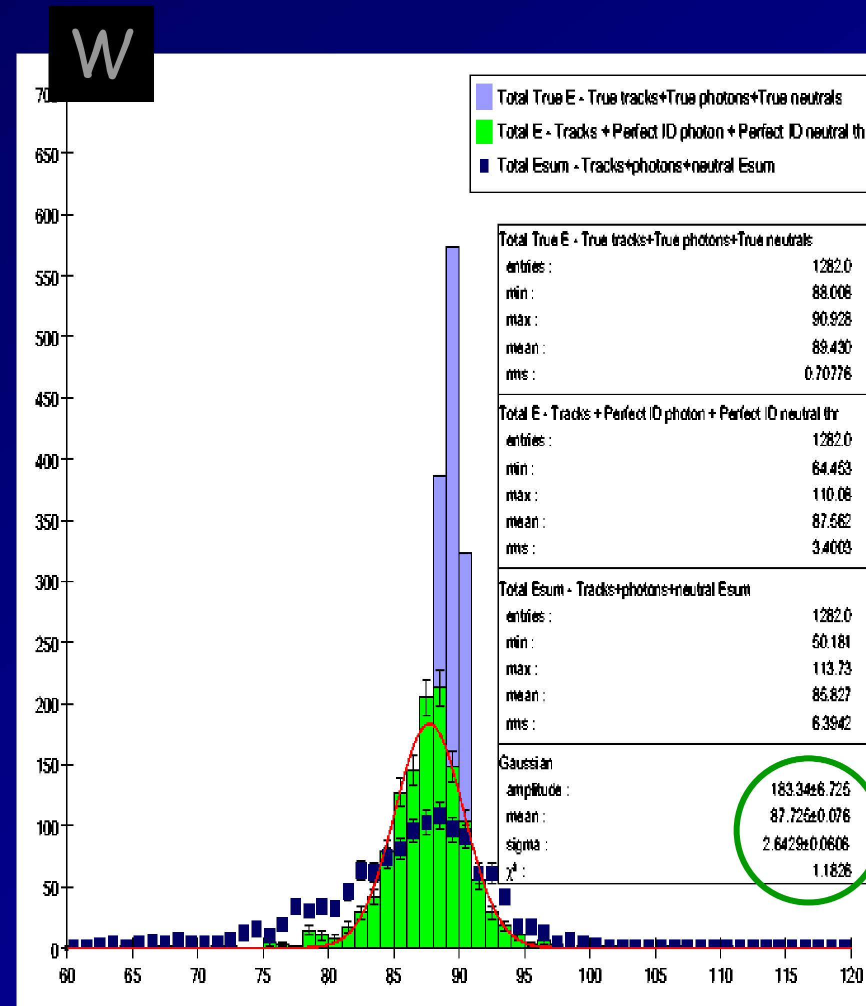




Both exhibit linear behavior for number of hits vs energy
-> more hits per GeV in W (same as for single pion)

e+e- -> Z (jets) - PFA performance





True PFA

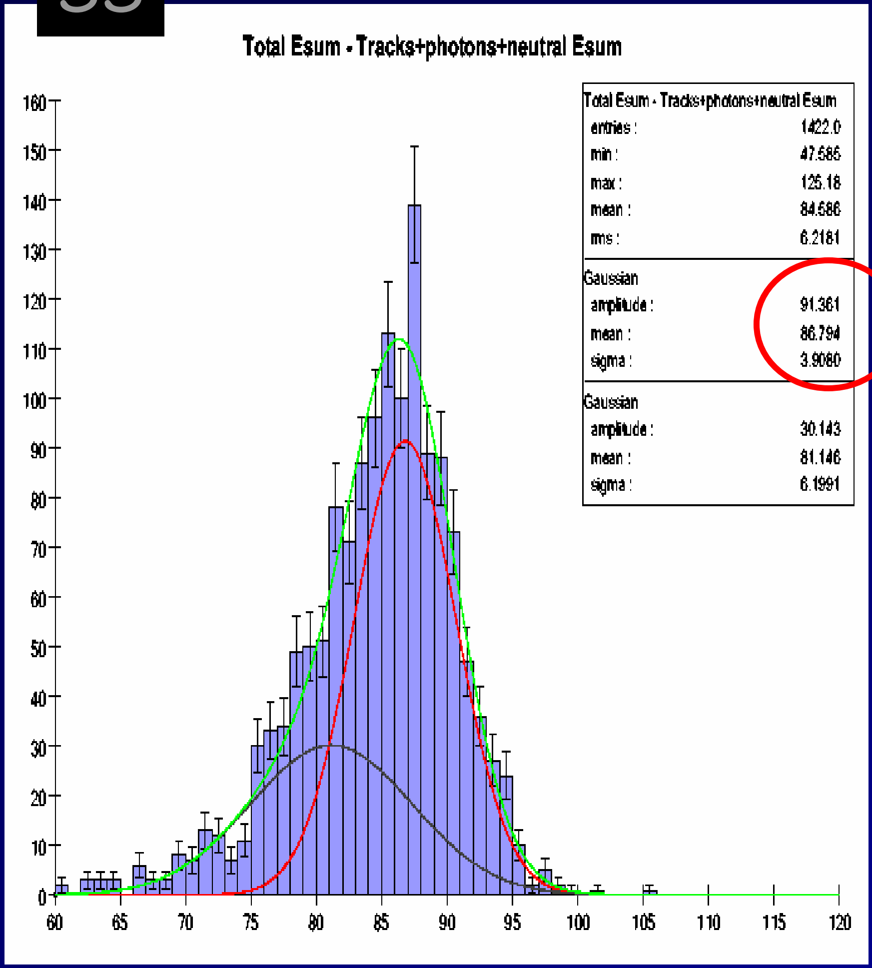
-> SS 33%/√E

-> W 28%/√E

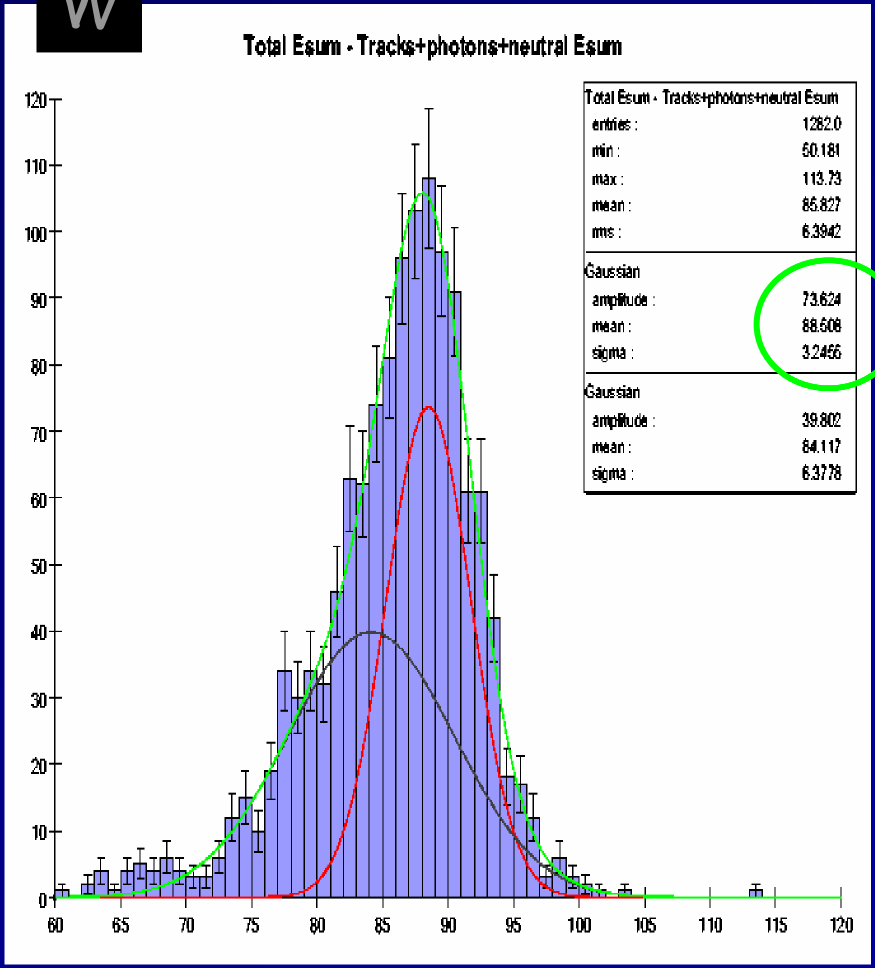
Compare current PFA with true . . . Fit ->

e+e- -> Z (jets) – PFA performance Fits

SS

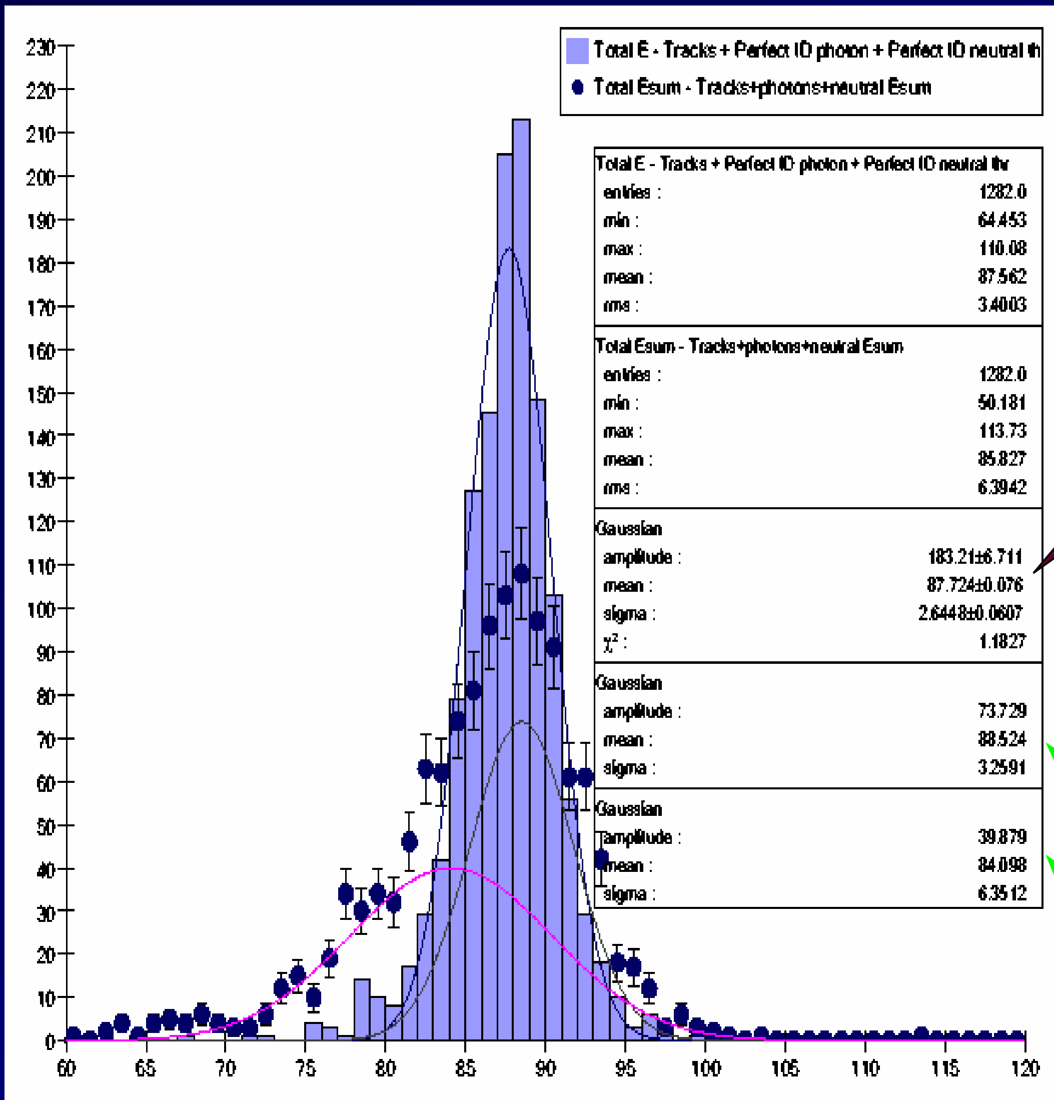


W



Better PFA performance with the W HCAL for conical showers . . .
however, simple iterative cone reconstructs smaller fraction of events

PFA Development Status – True vs Current PFA



True PFA (no confusion)

-> 28%/√E

Current PFA Status

35%/√E (conical showers)

70%/√E (needs work!)

Summary

PFA Status

-> iterative conical shower algorithm approaching true PFA performance goals (~50% of charged particle showers in CAL)
-> remaining showers need more sophisticated approach (shower "tree" reconstruction using density-weighted or energy weighted seeds)

HCAL Absorber Material

-> PFA performance not compromised with a shorter, denser HCAL (in fact, improved!)
-> major cost savings if magnetic coil radius can be reduced
-> last 10 layers of ECAL will sample at 1.4 X_0
-> using W for absorber with 2 X_0 sampling improves PFA performance (more hits?) while reducing the coil radius

PFA Understanding

-> studies like this will help us to understand the dependence of PFA performance on calorimeter parameters leading to an optimized PFA and Calorimeter